

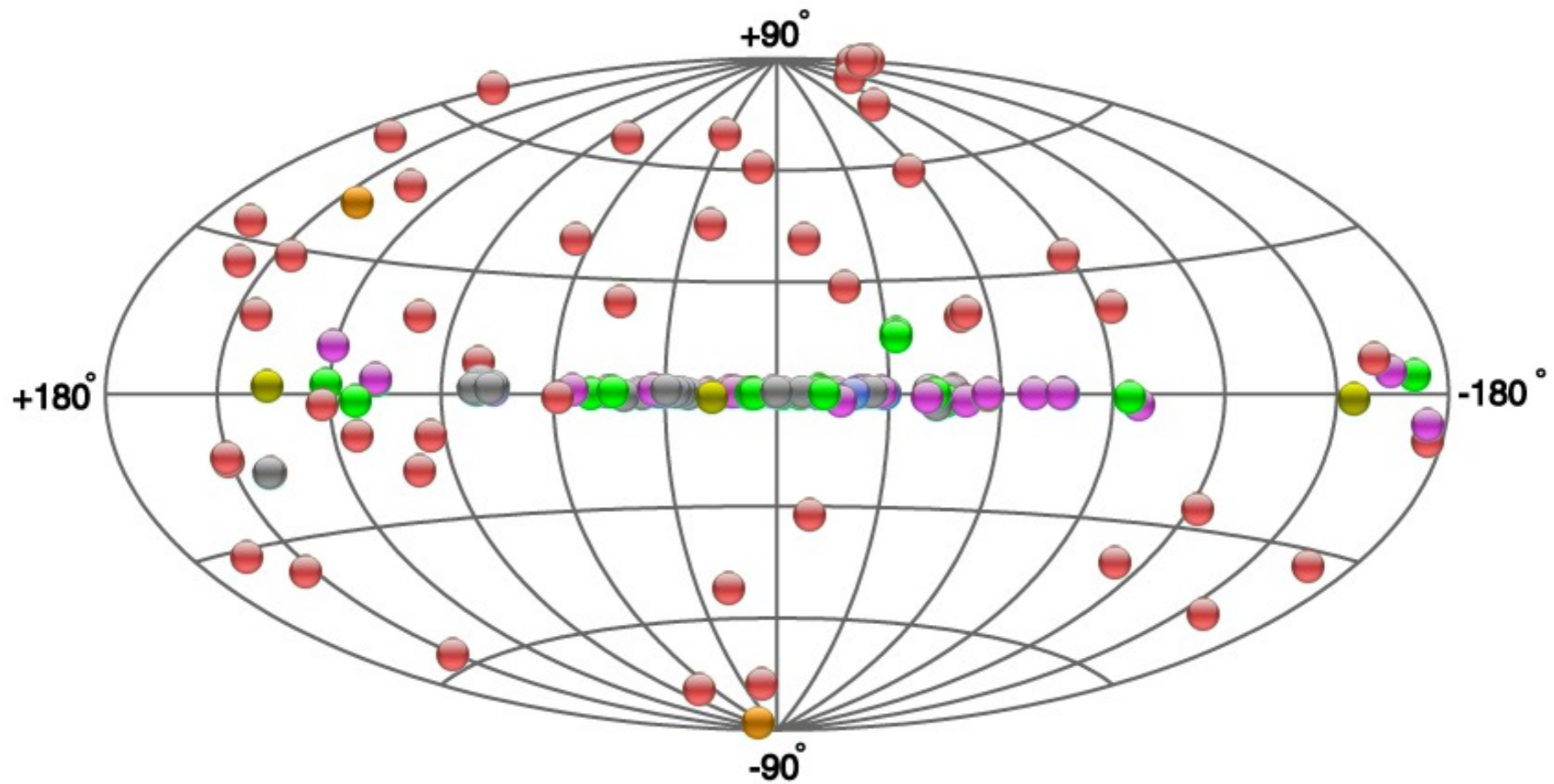
# Cherenkov & Jansky: Our Understanding of AGN at the Highest Energies

Jeremy S. Perkins (CRESST/UMBC/GSFC) on behalf of  
the VERITAS and *Fermi* LAT Collaborations

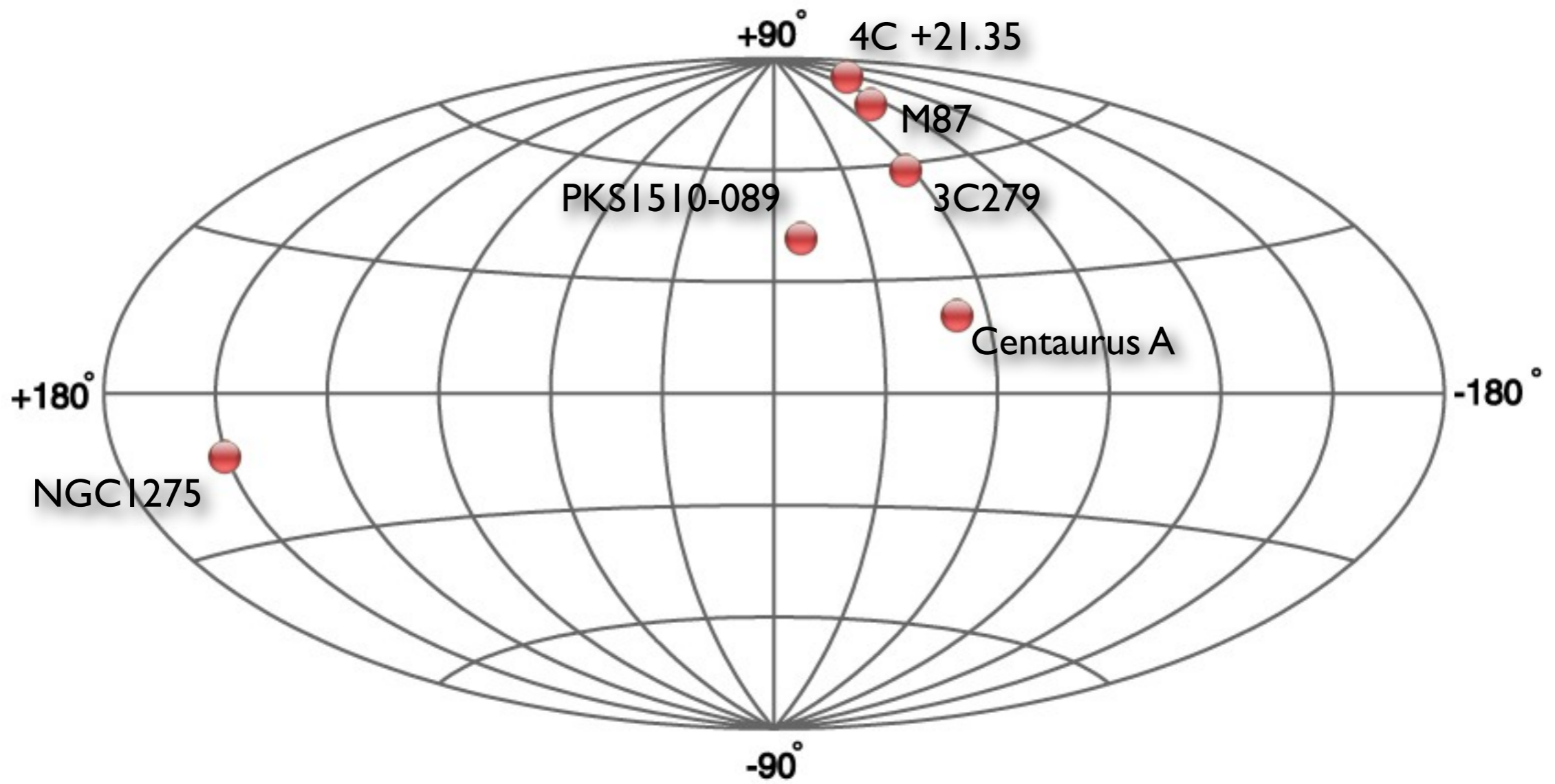
# VHE: $E > 100 \text{ GeV}$

- Necessarily ground based - cannot get enough effective area with space based instruments (Effective Area  $\sim$  Football Field.
- Uses some type of Cherenkov technique:  
Air (atmosphere) or Water
- Three major arrays: VERITAS, HESS, MAGIC
- Upgrades done or are happening: MAGIC2, HESS2, VERITAS Upgrade
- New generation coming soon: HAWC, CTA

# Over 120 VHE Sources, About 40 Blazars



<http://tevcat.uchicago.edu>



## 6 'misaligned' AGN

# Active Galactic Nuclei @ VHE

- AGN “Standard Model”: Black Hole and Accretion Disk Power Relativistic Jet
- Viewing Angle Determines Source Type
- Open Questions
  - Emission Mechanisms?
  - Jet Structure?
  - Black Hole Accretion?
  - Leptonic or Hadronic?
  - Emission Region?
  - EBL?
  - Quantum Gravity?

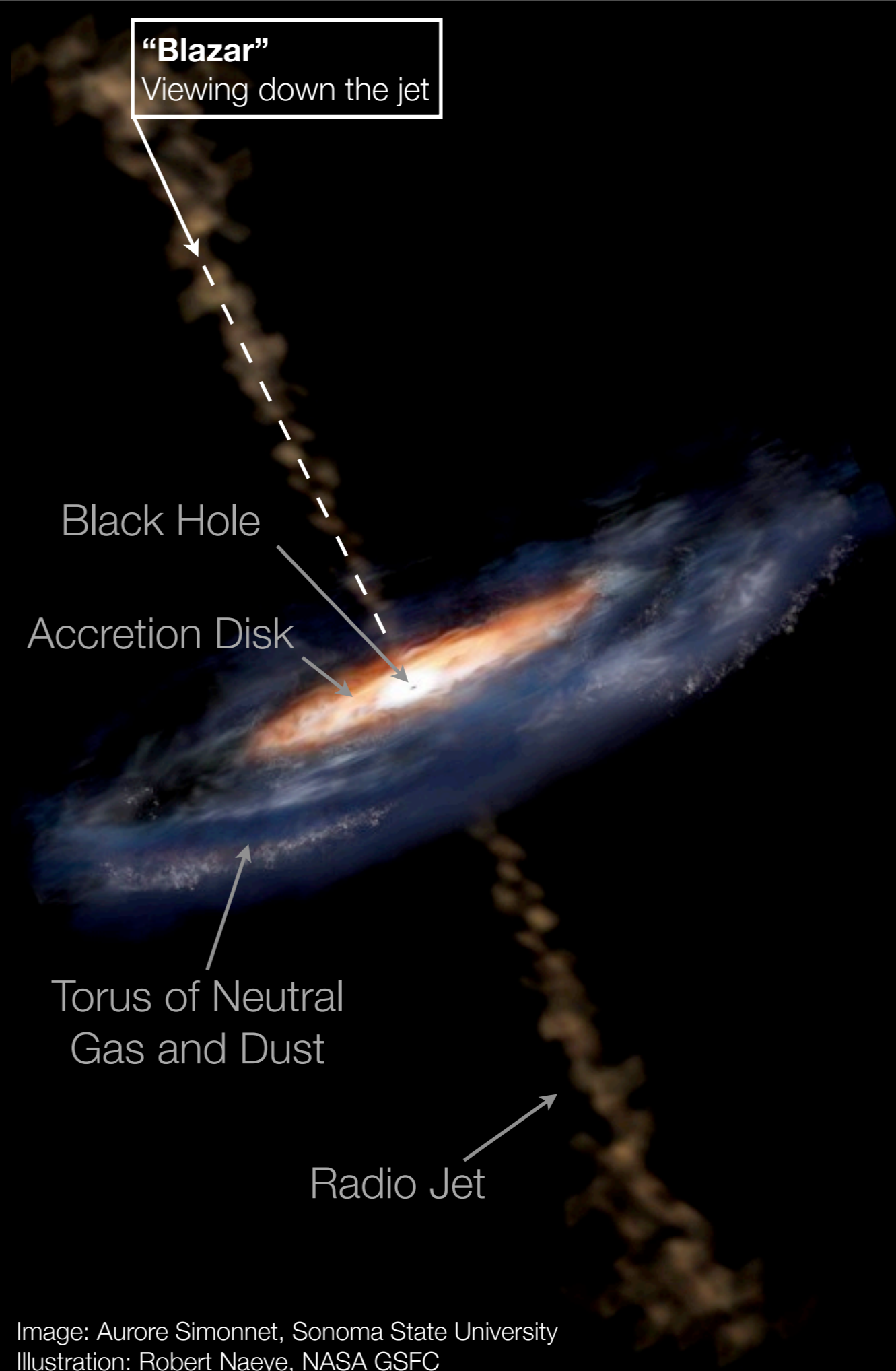
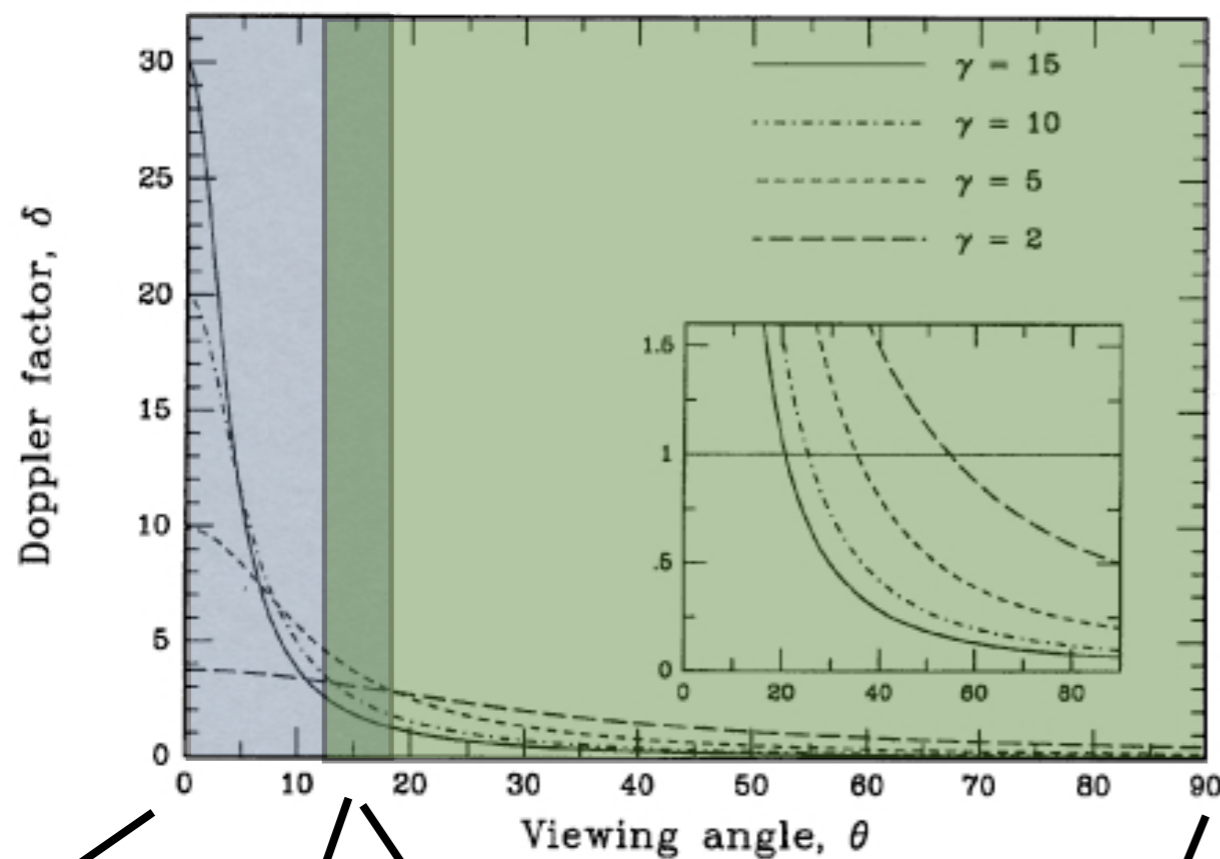


Image: Aurore Simonnet, Sonoma State University  
Illustration: Robert Naeye, NASA GSFC

# Why only a handful of misaligned Blazars?

Urry & Padova (1995)



Blazars

Radio Galaxies

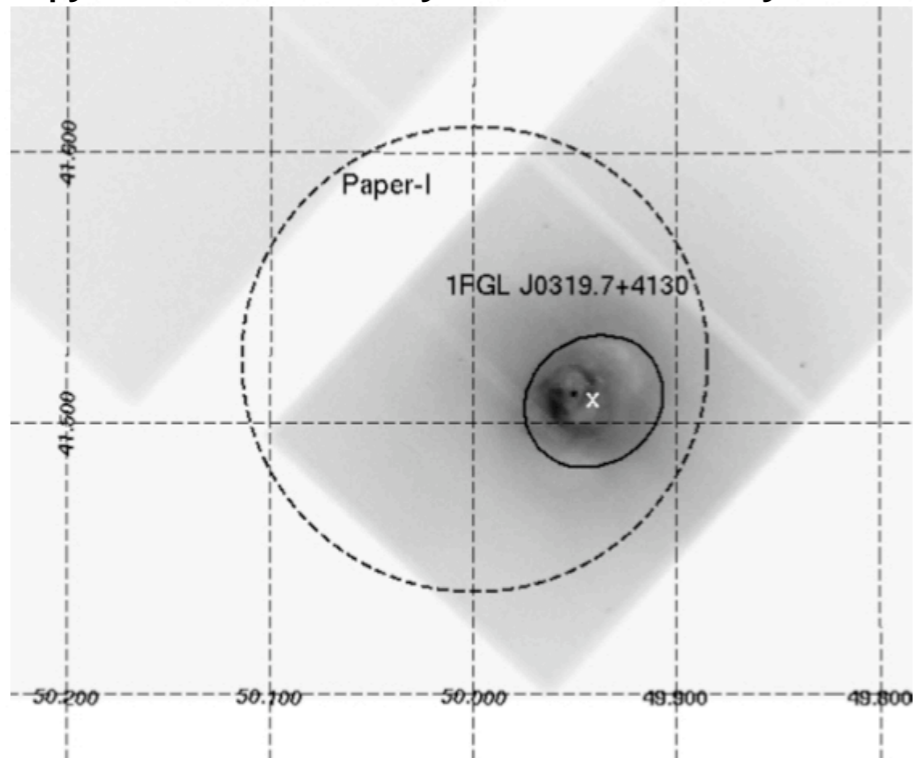
- Blazars benefit from high doppler factors and gammas.
- Jet emission possible at large theta but less beaming available. Same emission mechanism as in blazars?
- Possibly see lobe emission from regions outside of the core.

# What are we trying to Learn?

- Modeling - how do these fit in with the emission seen from blazars?
- Are FRI's the parent population of Blazars?
- Viewing different types of AGN provide clues to an overall AGN emission scheme.
- Complicated Geometries (like spline-sheath)?
- What's the location of the VHE/HE emission?
- Hadronic vs. Leptonic scenarios?

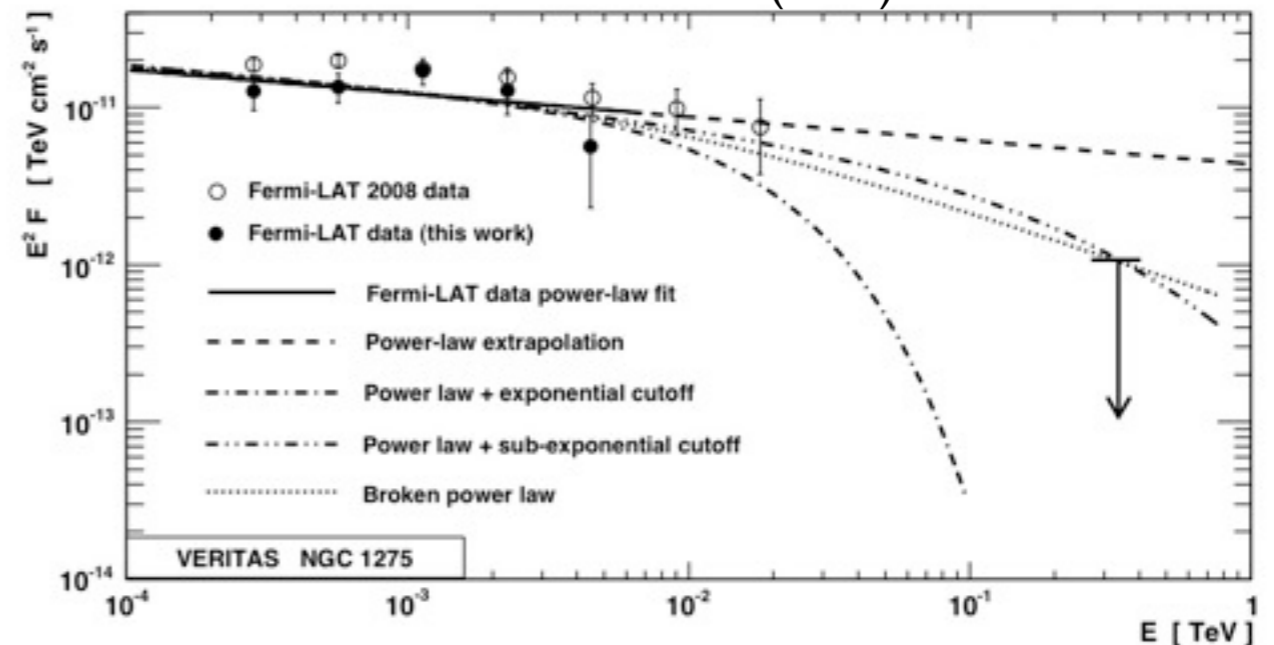
# NGC 1275

ApJ, 2009, 699 - lead J. Kataoka w/ MOJAVE



LAT 3-month and 11 month localizations. Evidence for long-term GeV variability (seen by Cos B, not by EGRET)

Acciari et. al. (2009) - lead N. Galante

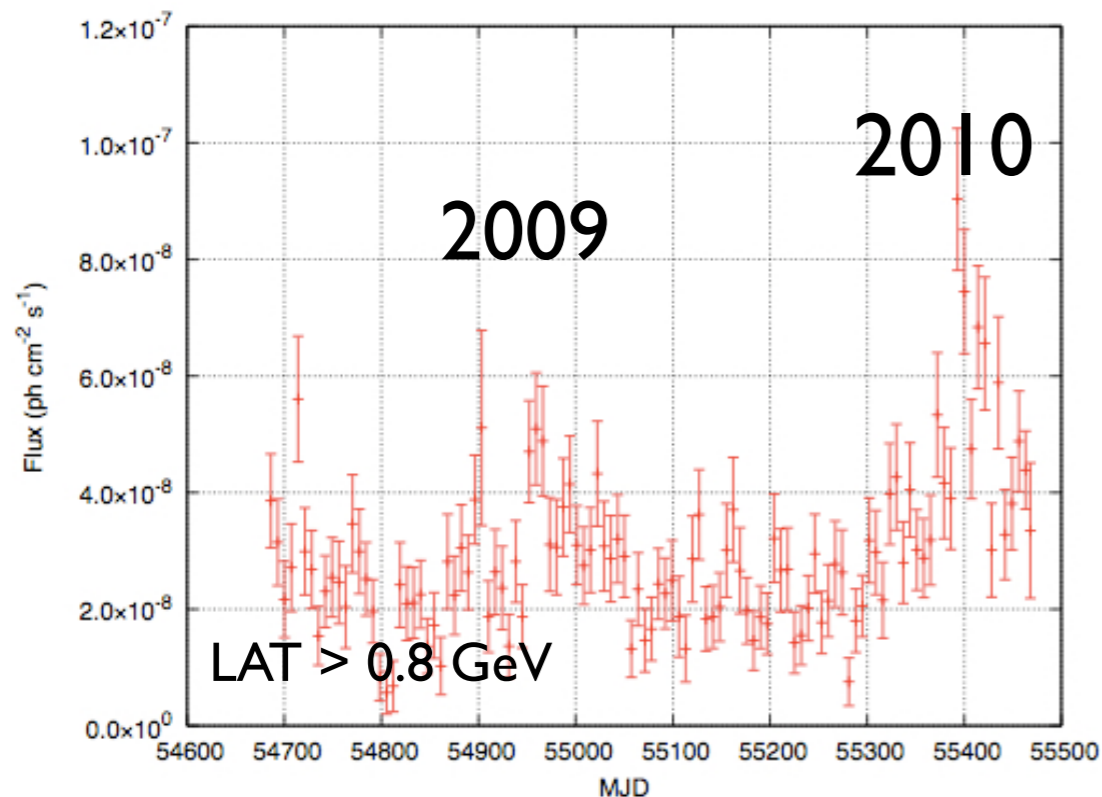


VERITAS upper limit combined with LAT measurement not compatible with a power-law.



# NGC 1275 Fermi

- Flaring seen in 2009 along with GeV hardening (Kataoka et al 2010).
- Large Flare seen in 2010 along with a VHE detection by MAGIC (Donato et al. Atel).



- These flares might correlate with Radio flares.
- Important to use radio/GeV to trigger TeV observations since nothing is usually seen.

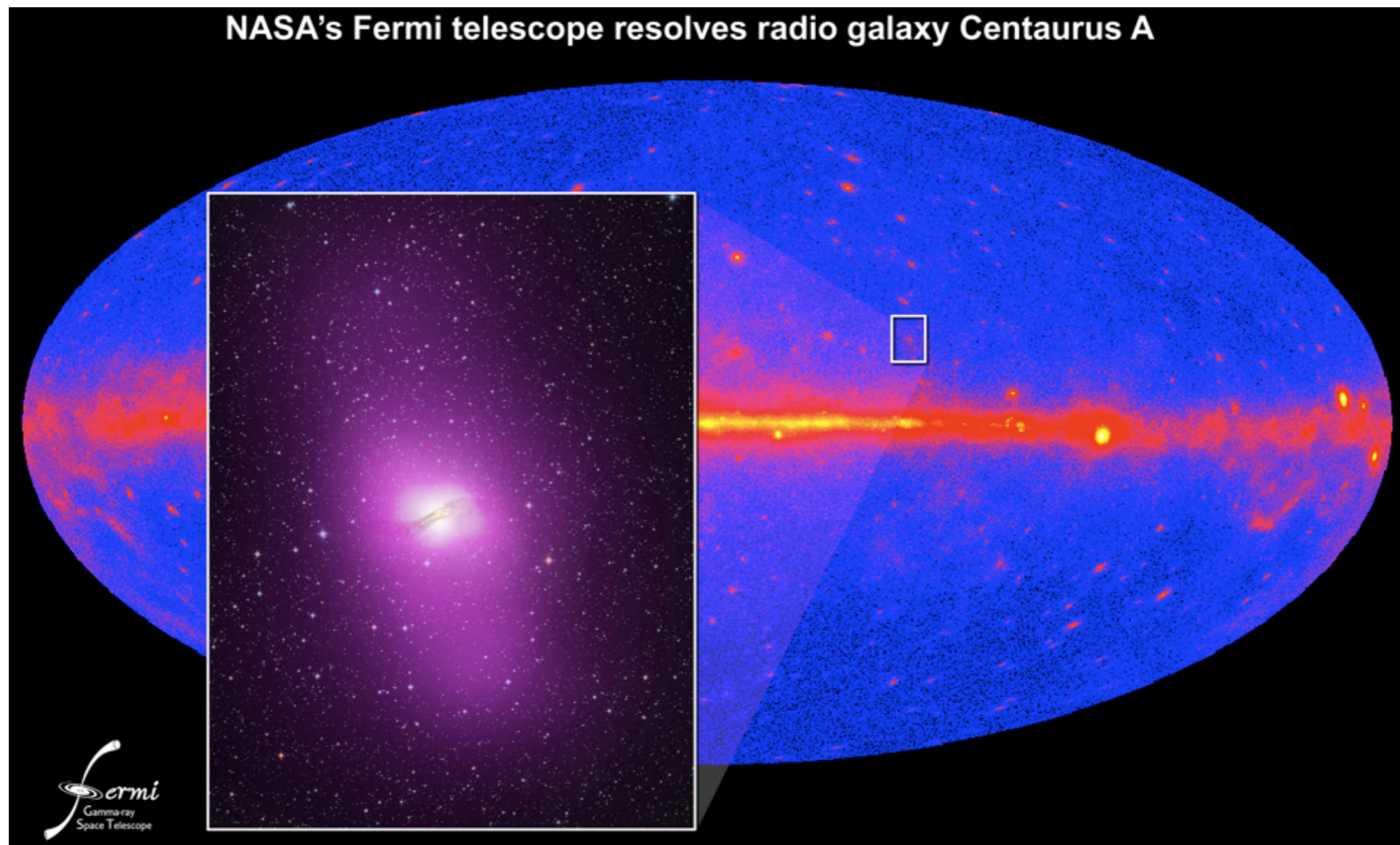
# Centaurus A

- Nearest (3.7 MPc) radio galaxy with giant radio lobes.
- The LAT 'sees' both the lobes and the core.
- 10 degree extent in radio.



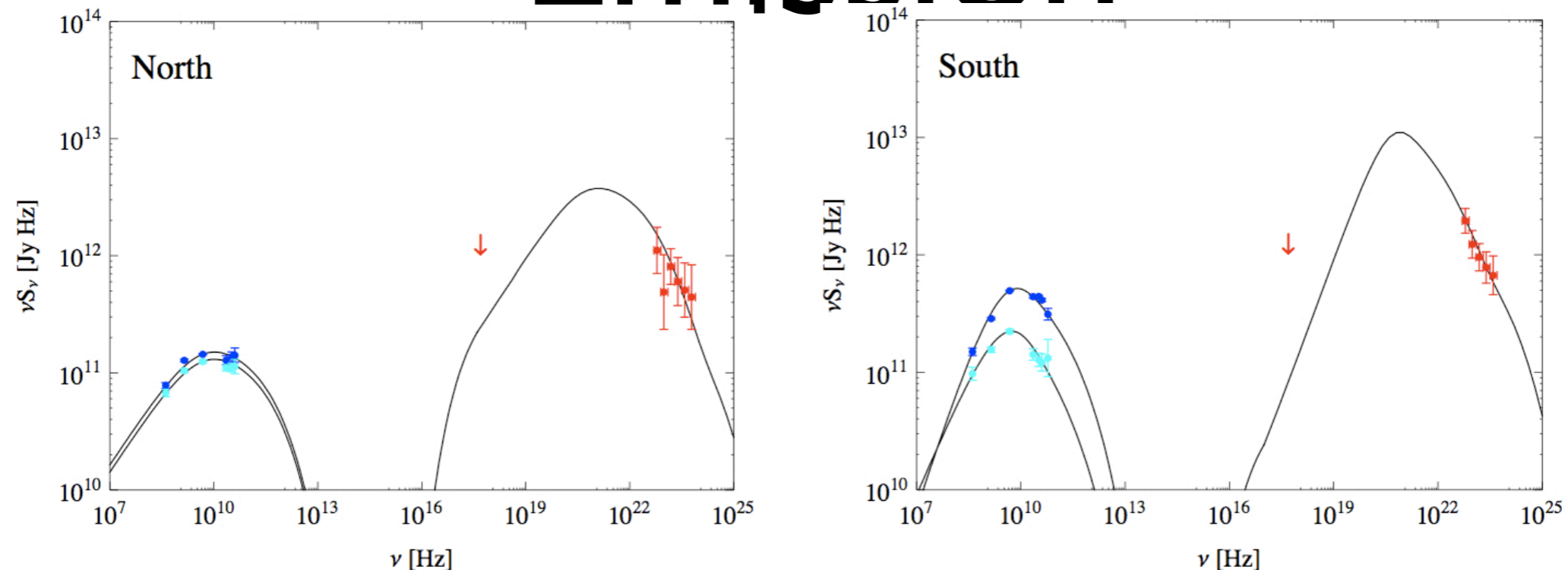
**Credit:** Ilana Feain, Tim Cornwell & Ron Ekers (CSIRO/ATNF); ATCA northern middle lobe pointing courtesy R. Morganti (ASTRON); Parkes data courtesy N. Junkes (MPIFR); ATCA & Moon photo: Shaun Amy, CSIRO

# Cen A: LAT detection



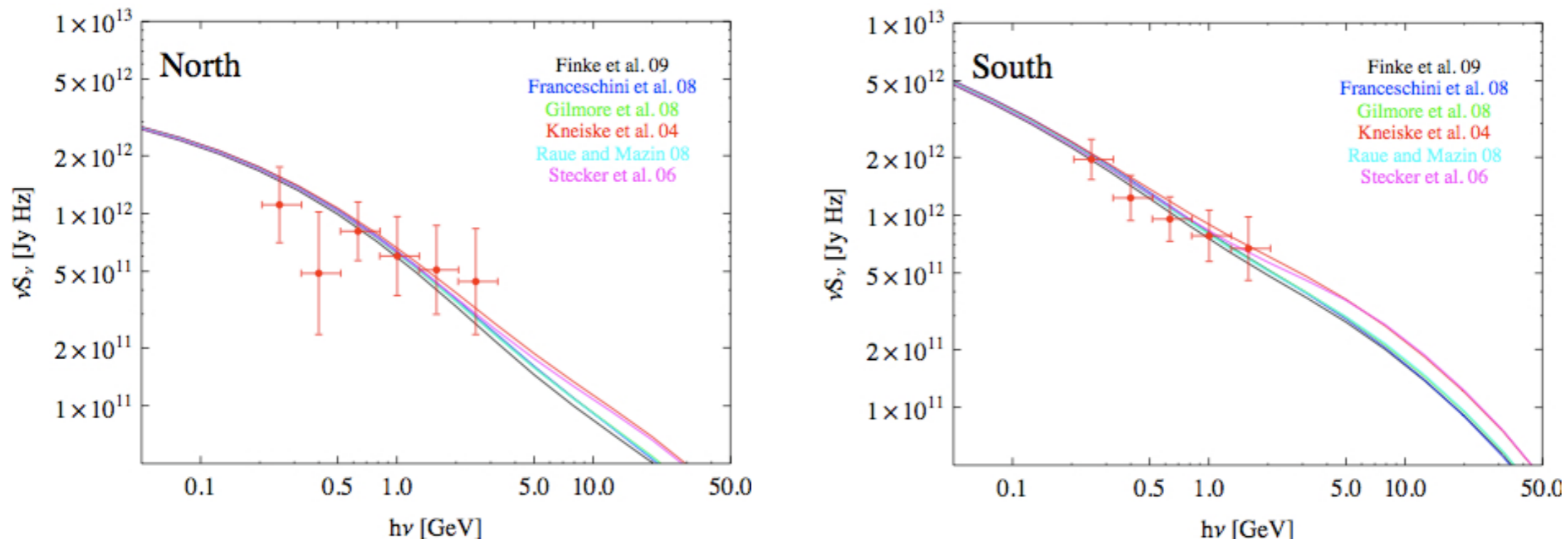
Science, 2010, 328 - Lead by Cheung, Fukazawa, Knodlseder and Stawarz

# Inverse Compton Emission



- IC (CMB+EBL) origin of LAT emission with  $B \sim 1$  uG (near equipartition).
- IC component dominant,  $U_{\text{cmb}}/U_B \sim 10$  means that the B-field is low in the lobes compared to other sources.
- Should see hard X-ray emission (not seen)

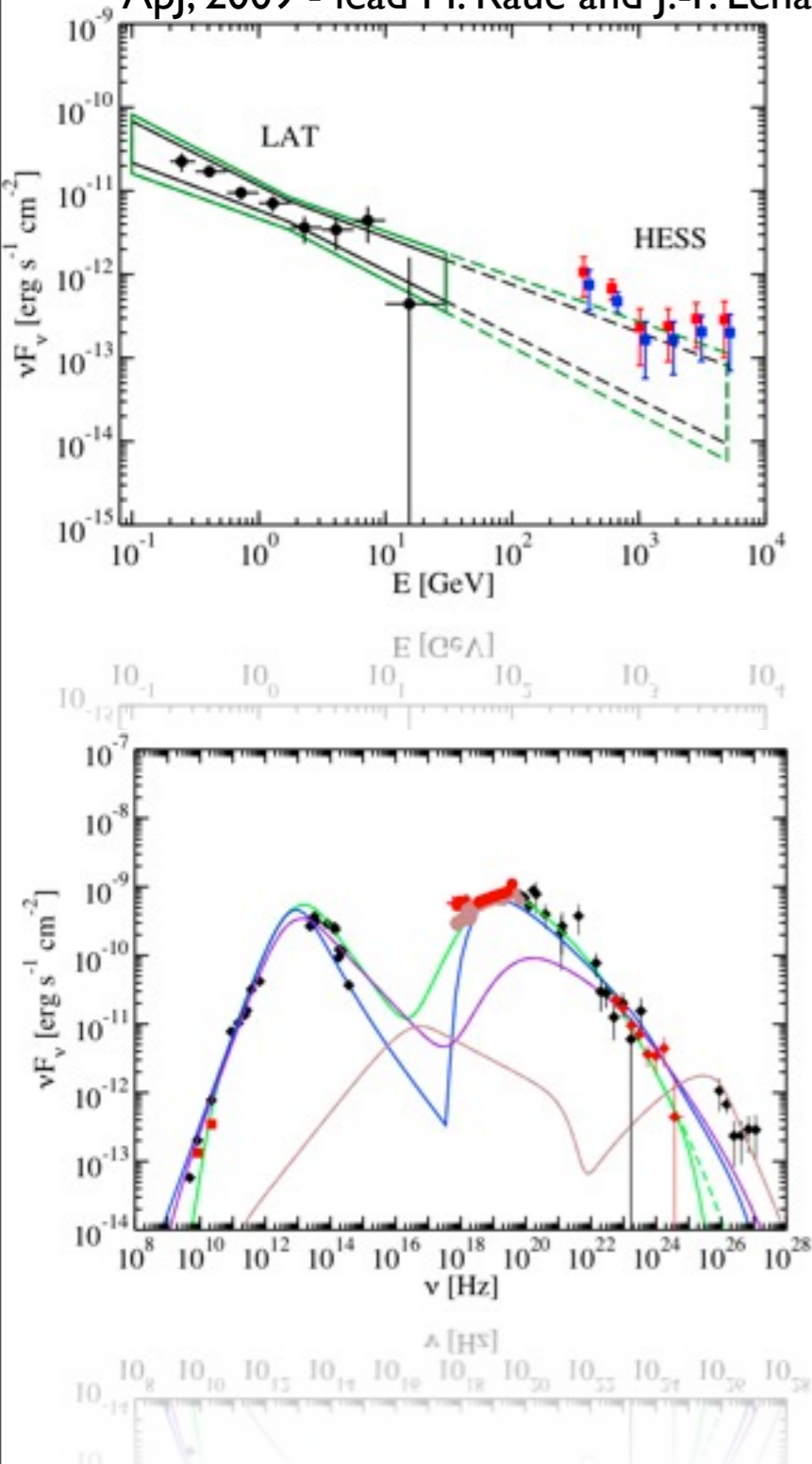
# EBL Probe



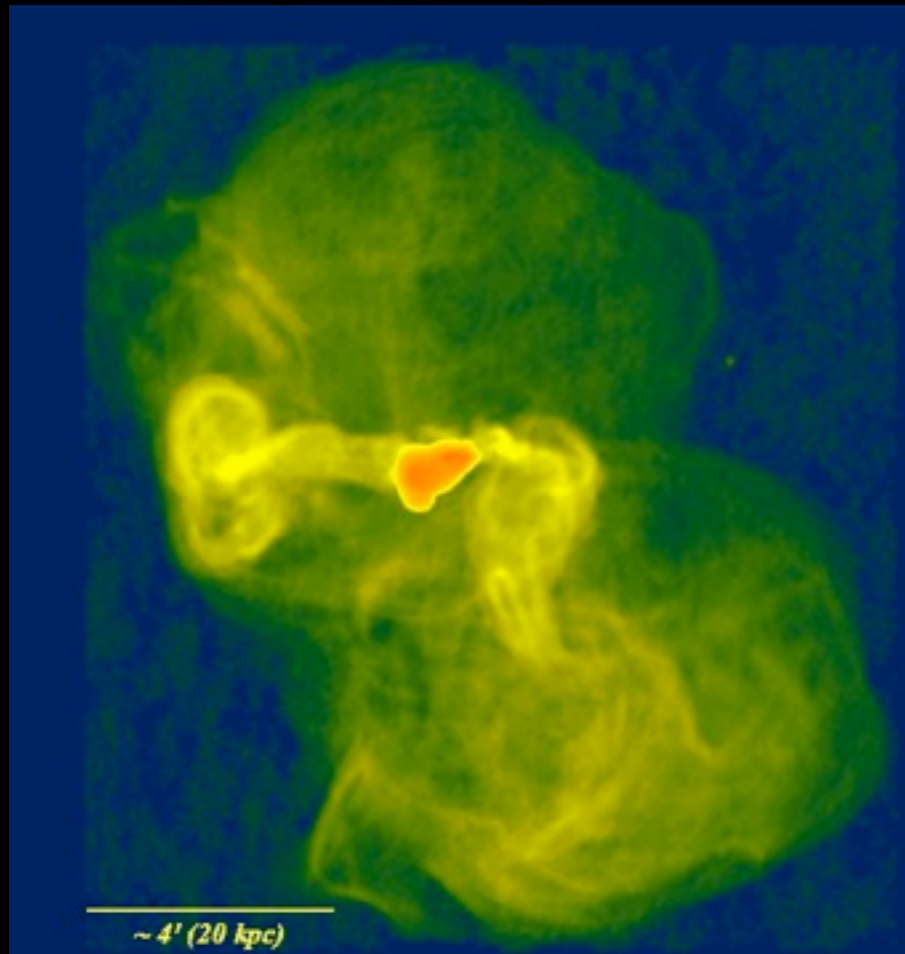
- Could probe EBL as IC/EBL dominates here at energies above  $\sim$  GeV.
- Deeper analysis is underway using the full 3 year dataset.

# VHE Detection

ApJ, 2009 - lead M. Raue and J.-P. Lenain

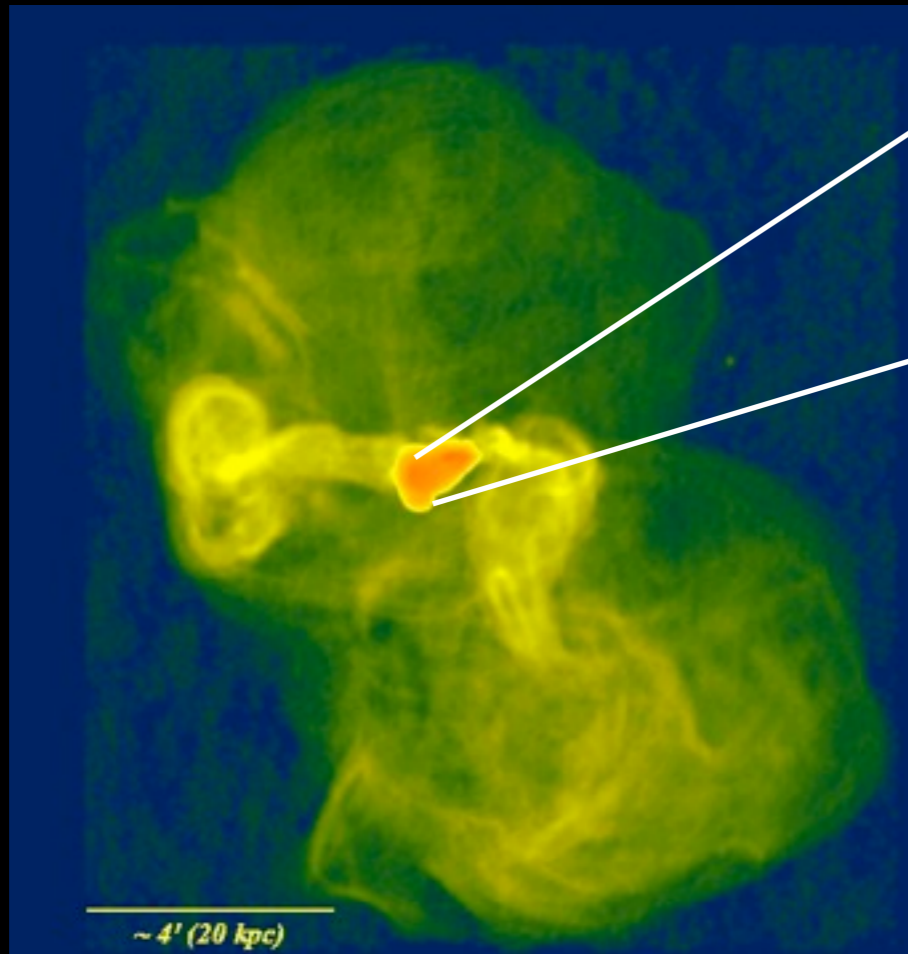


- Detection by HESS (long integration)
- VHE/HE spectra are barely consistent.
- IF FR I's are the parent population of blazars than SSC model should work but an SSC cannot explain the VHE emission
- Different emission regions?

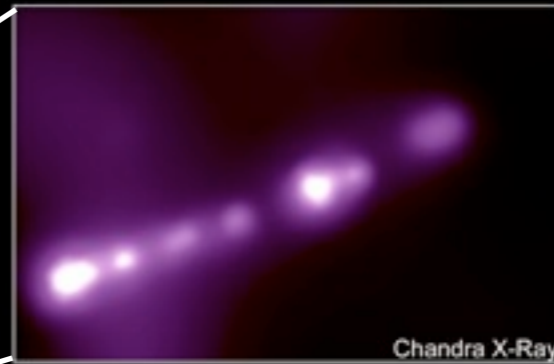


90 cm VLA (NRAO/AUI/NSF)

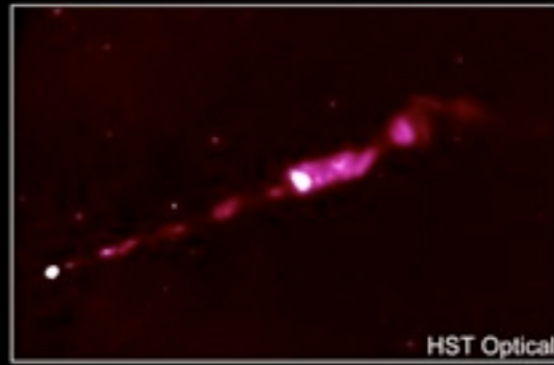
NEED REFERENCES FOR THESE  
PLOTS!!!!



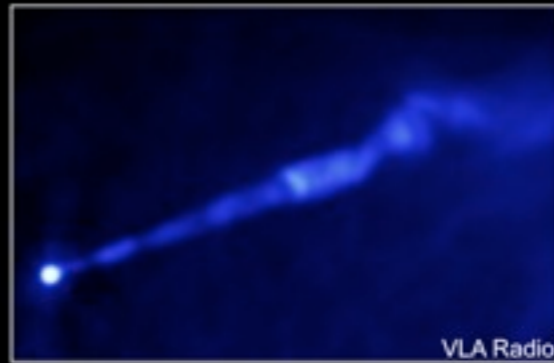
90 cm VLA (NRAO/AUI/NSF)



Chandra X-Ray



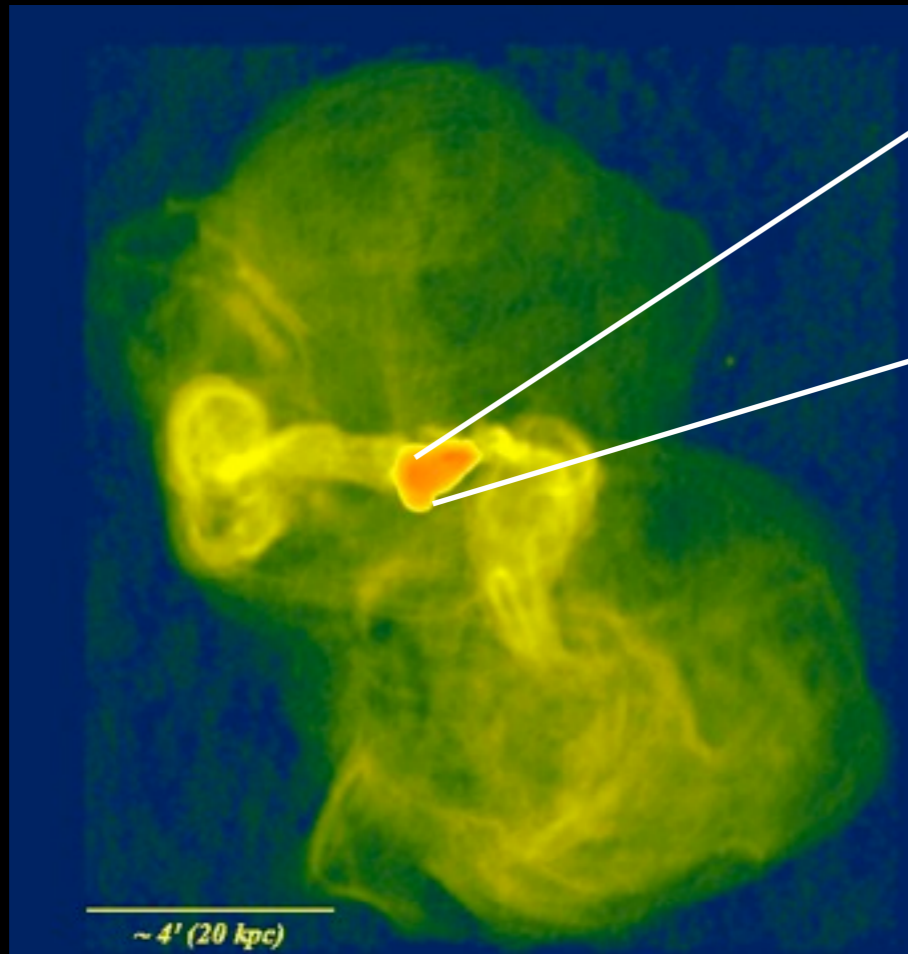
HST Optical



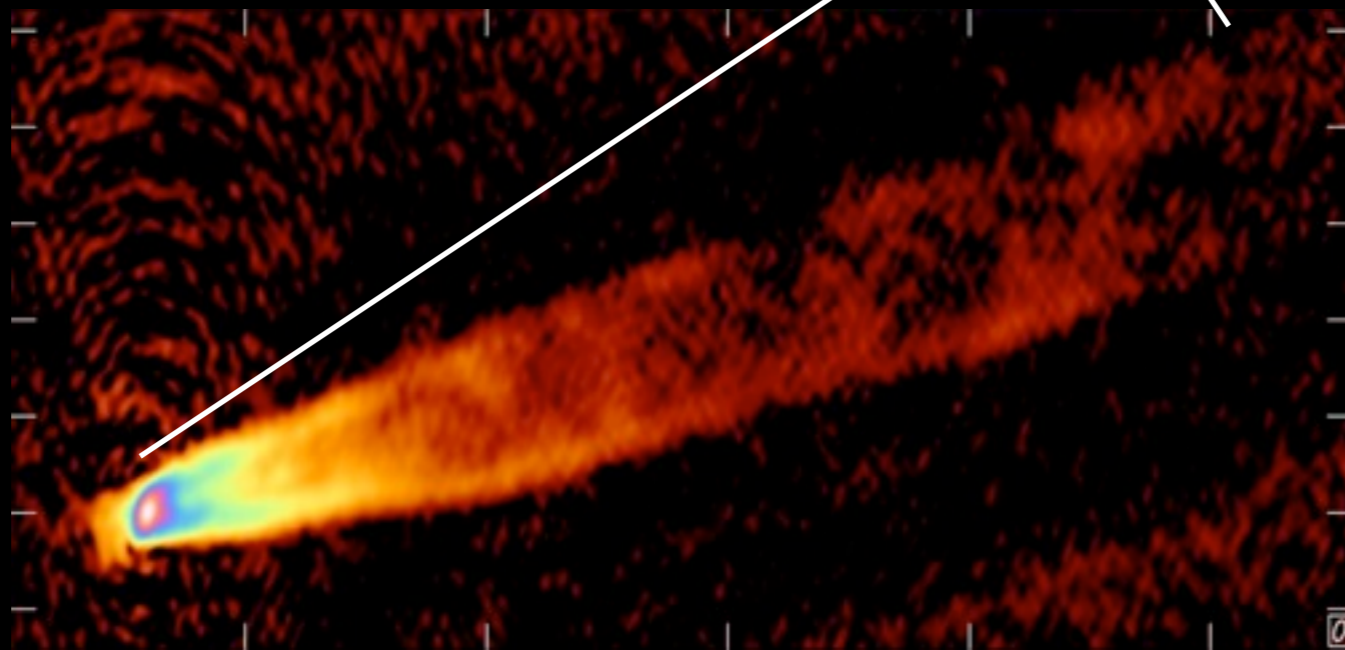
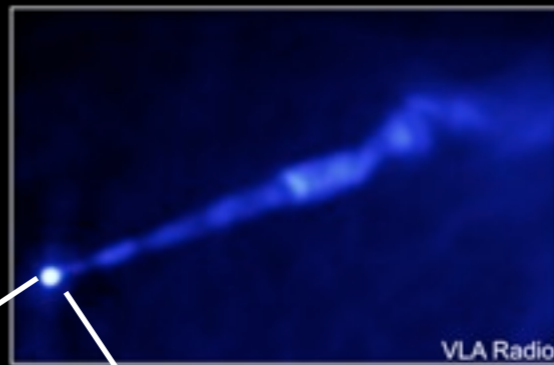
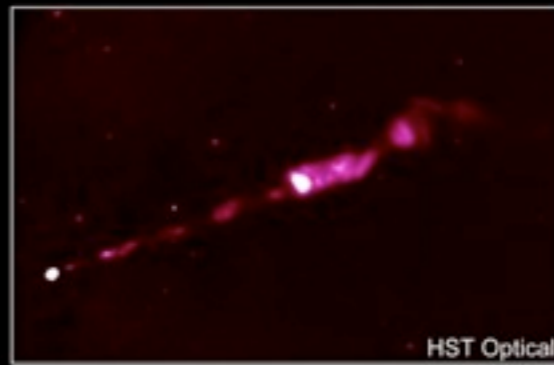
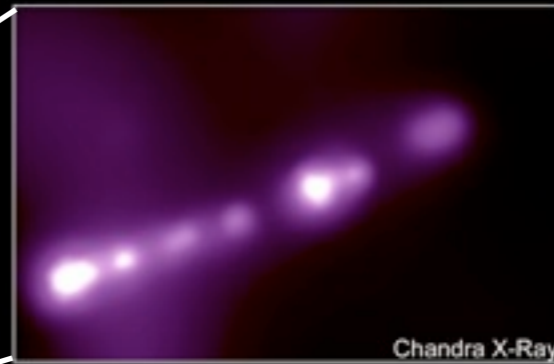
VLA Radio

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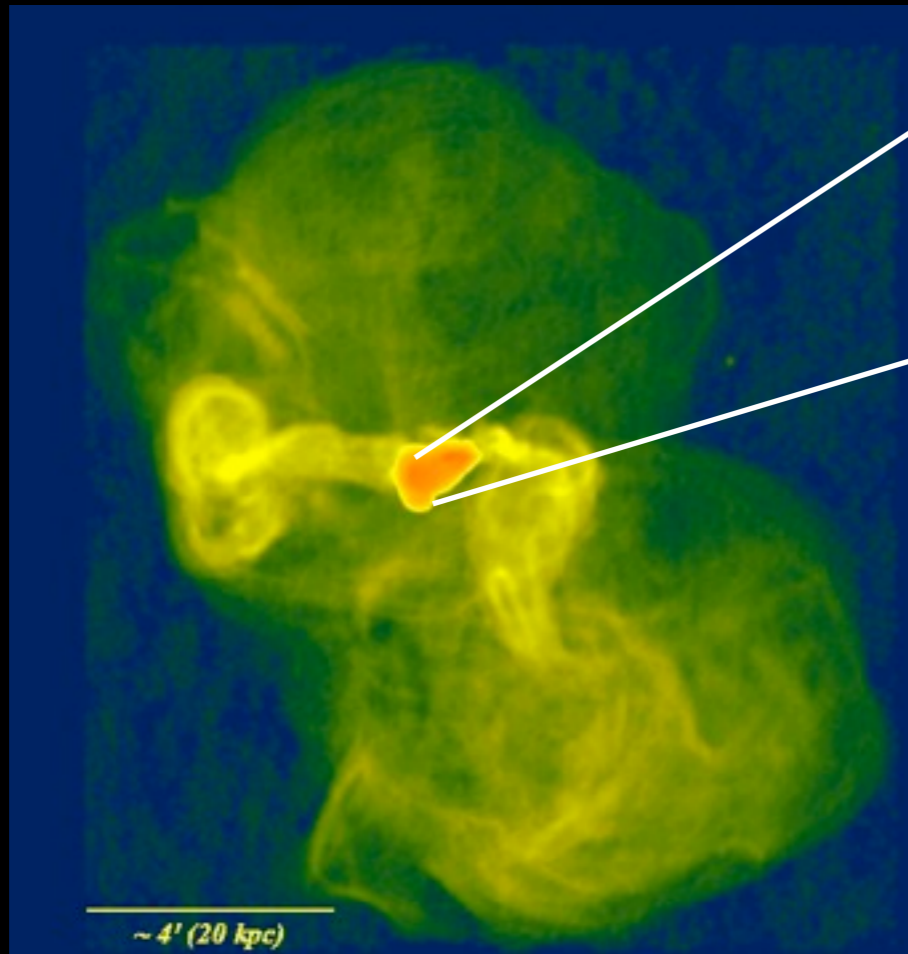


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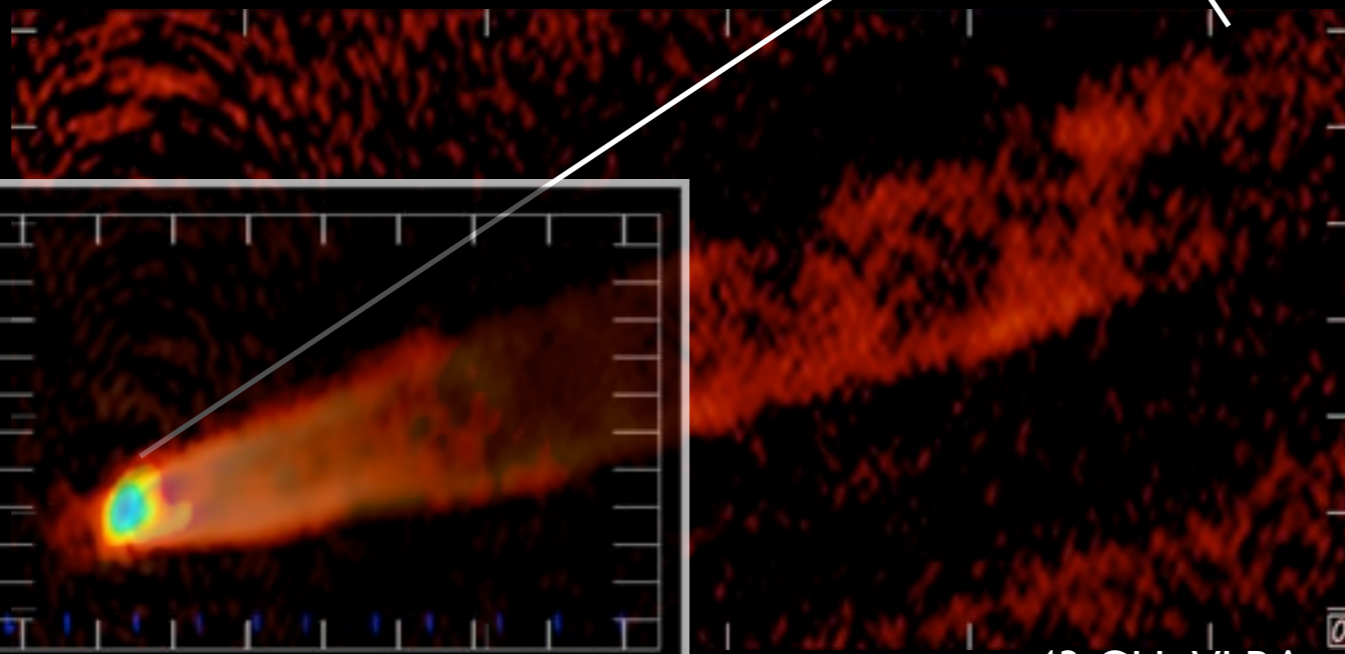
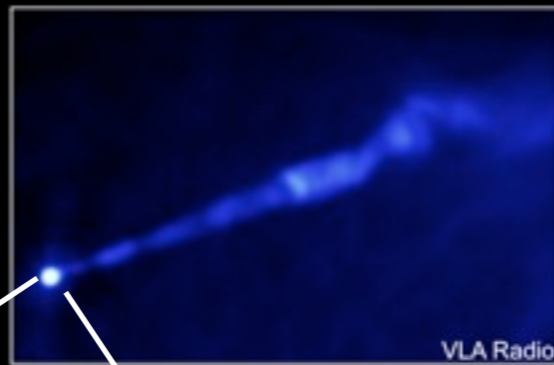
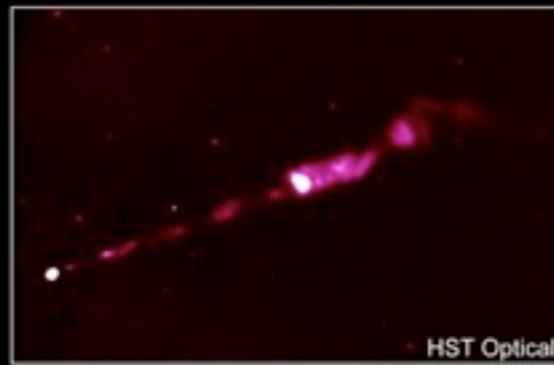
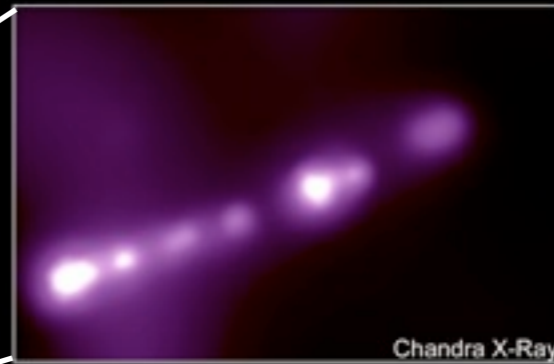


43 GHz VLBA

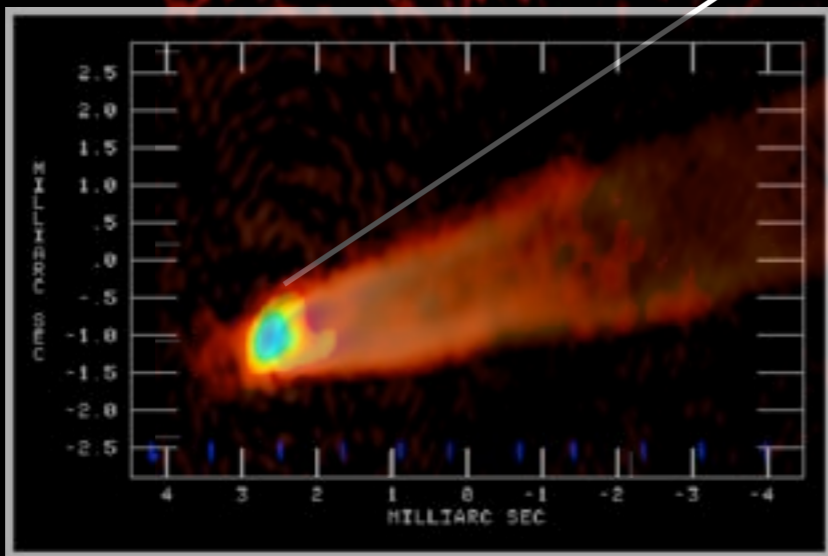
NEED REFERENCES FOR THESE PLOTS!!!!



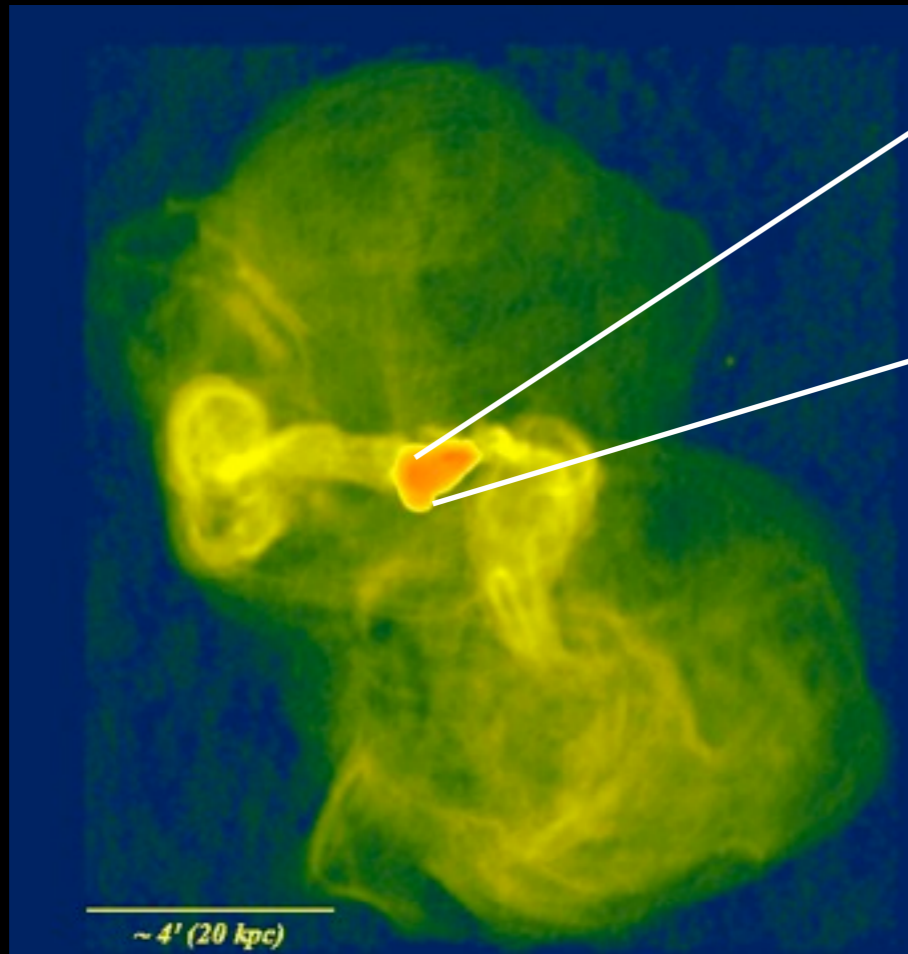
90 cm VLA (NRAO/AUI/NSF)



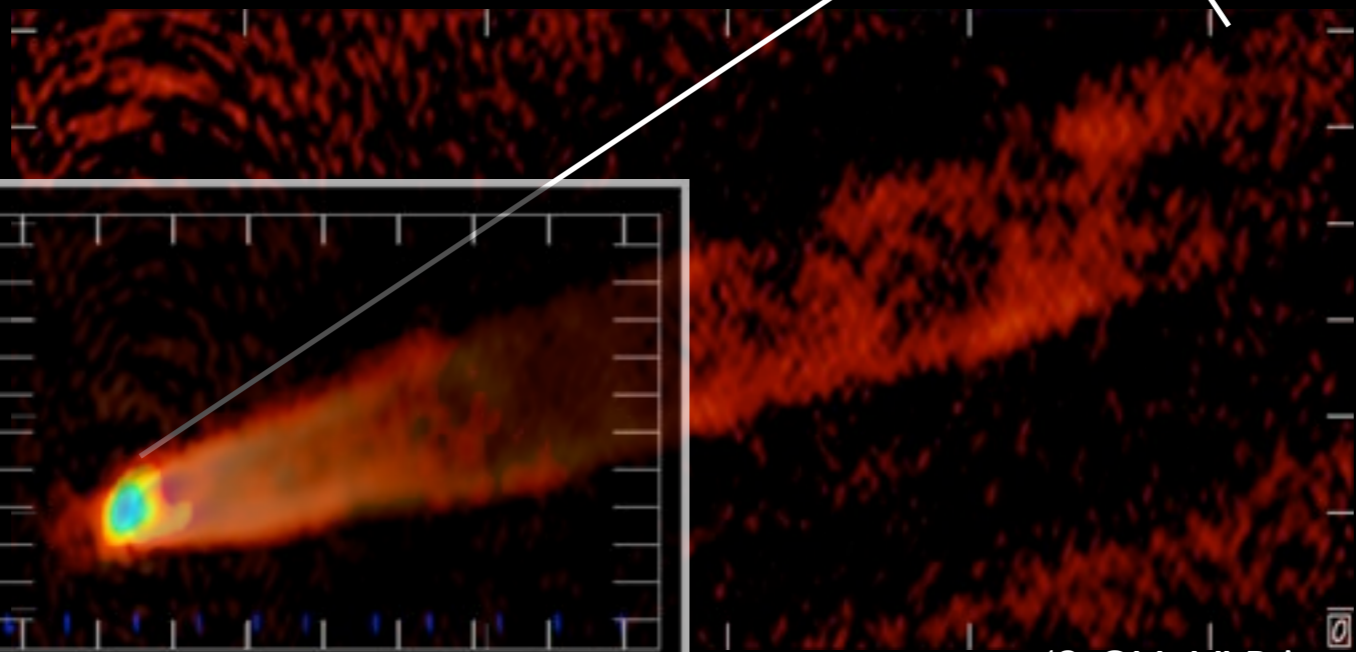
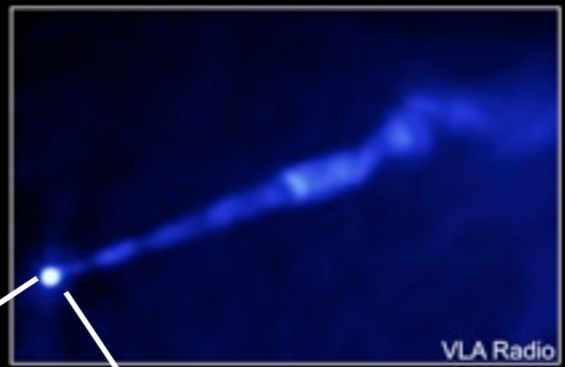
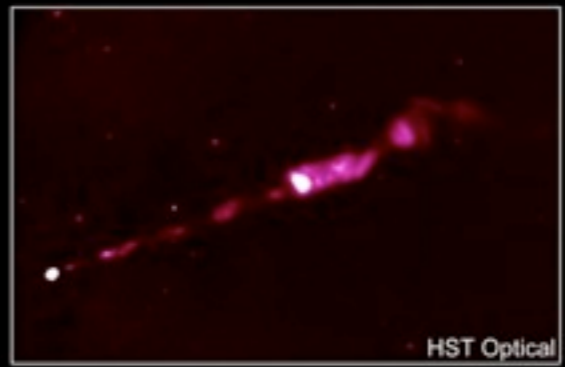
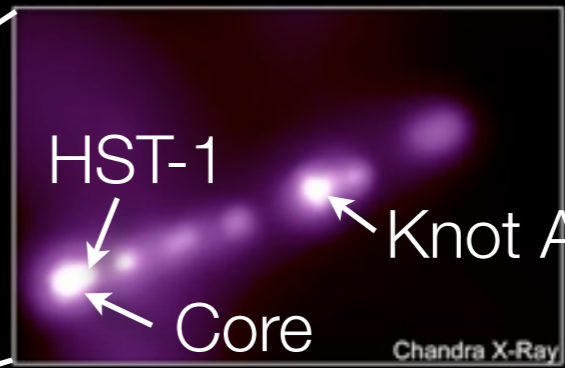
43 GHz VLBA



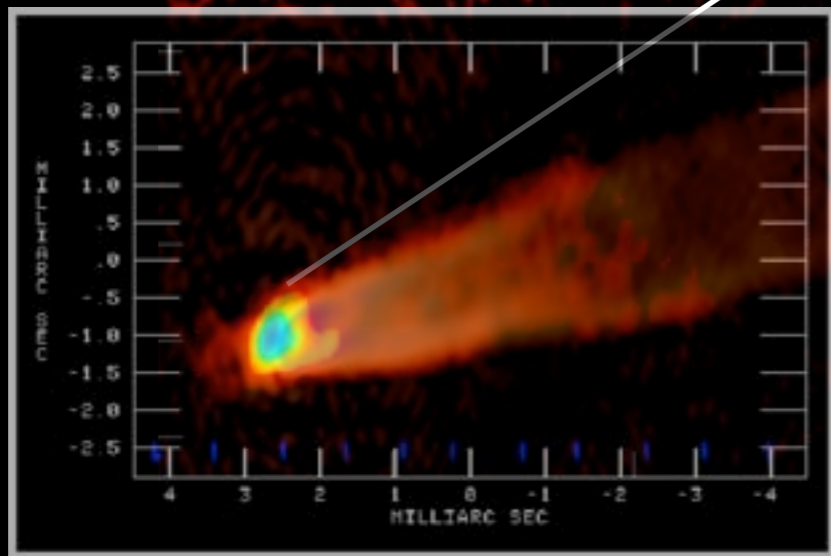
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90 cm VLA (NRAO/AUI/NSF)



43 GHz VLBA

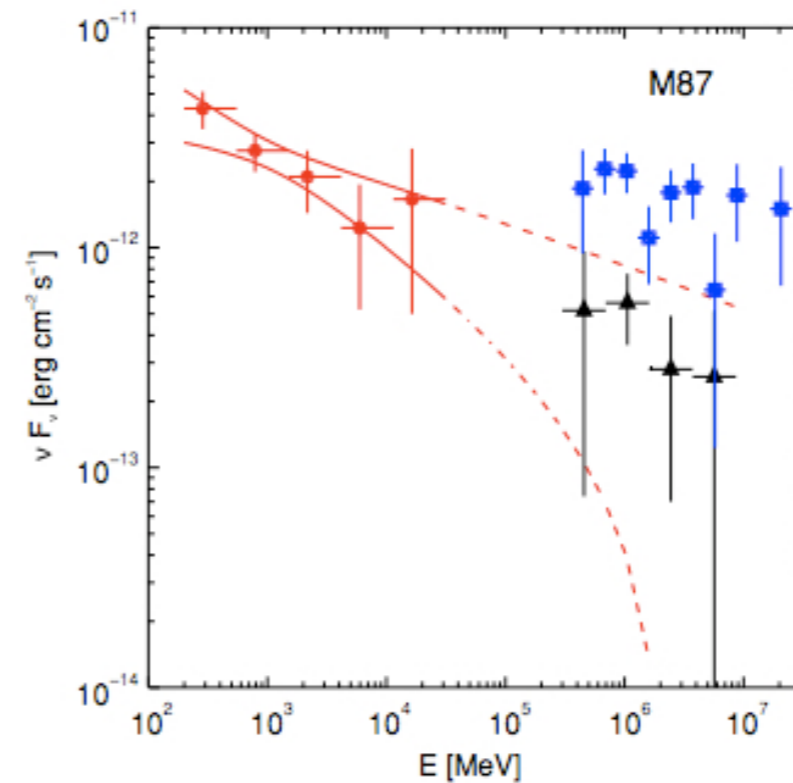
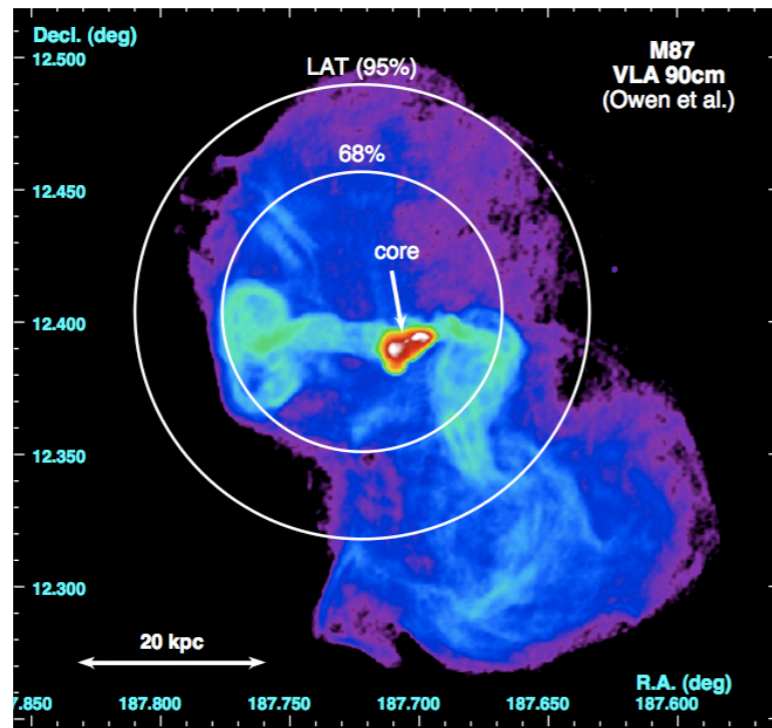


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# M87: The One and Only

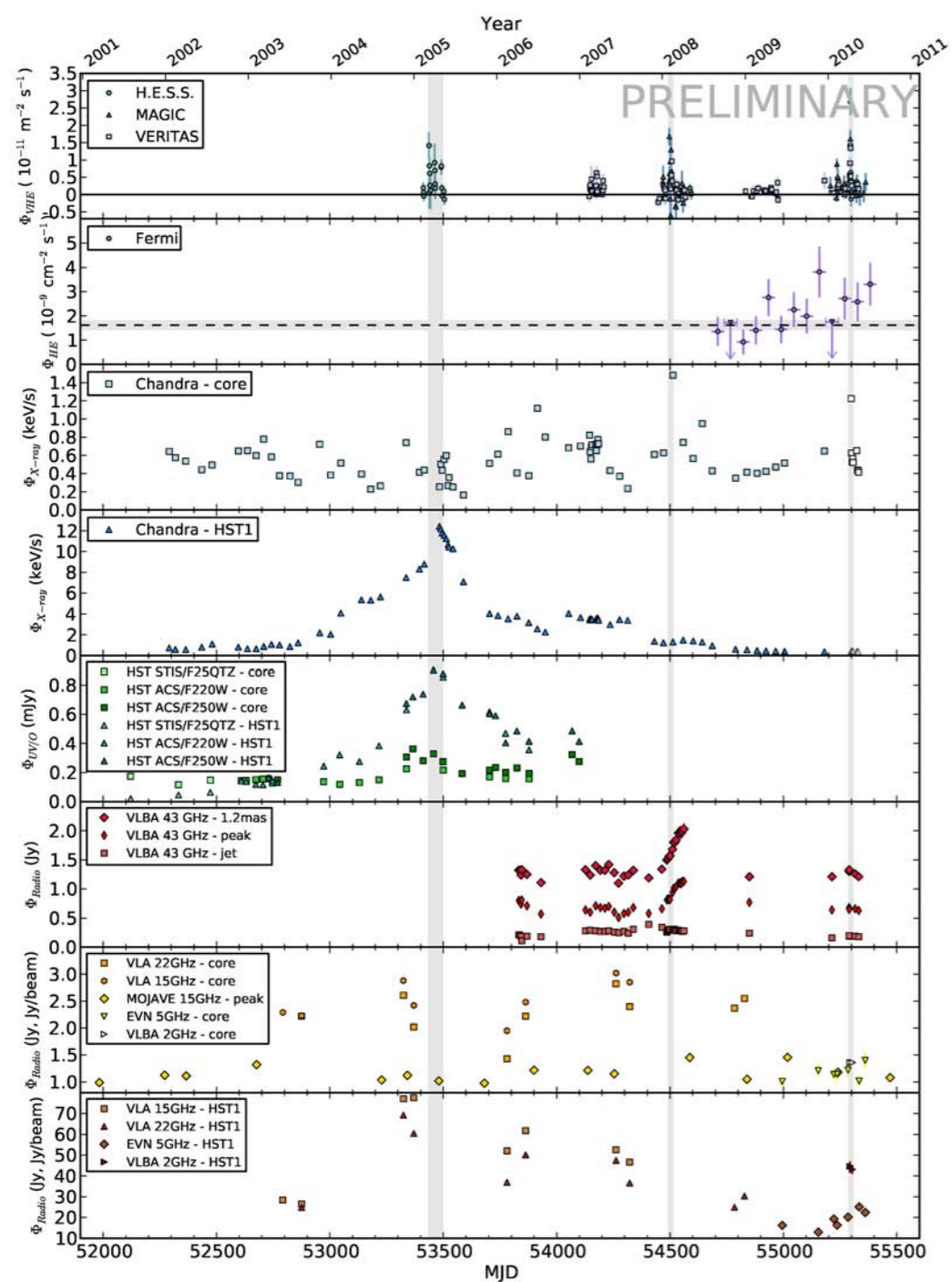
- Only non-blazar AGN detected by the previous generation of VHE instruments.
- What did we learn about it - EGRET?
- Jet Angle  $\sim 30$  degrees
- Distance  $\sim 16$  Mpc (no EBL, resolved structures in radio)
- Central Black hole:  $M \sim 3 \times 10^9 M_{\odot}$

# LAT Understanding



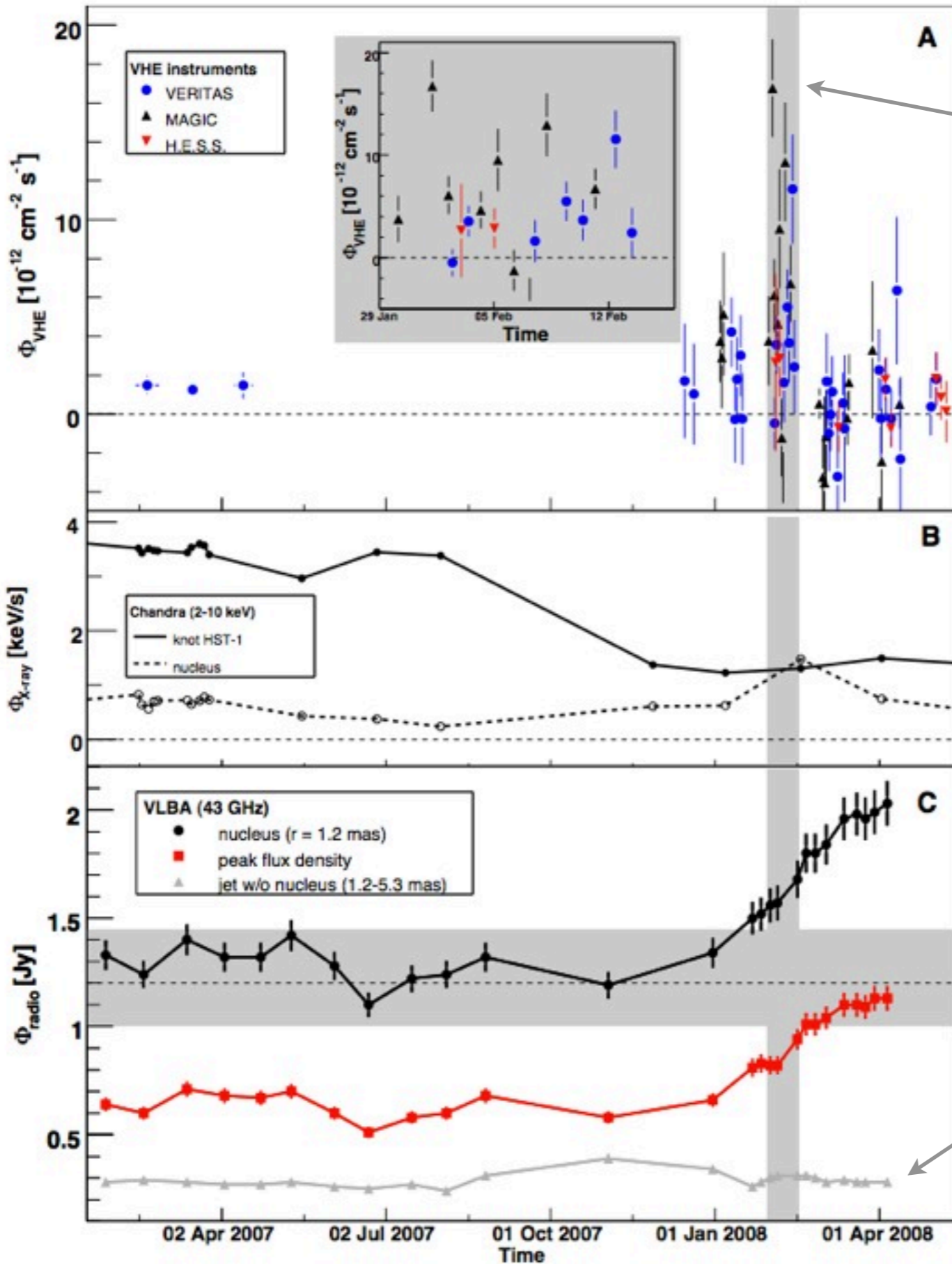
- MeV/GeV emission is I zone SSC with moderate jet beaming:  $d \sim 2-4$
- Does not preclude non-core emission

- **2005 Flare description will be here.**



- 2005 TeV flare (HESS) coincided with X-ray/UV/radio flaring in knot HST-1 ( $> 120 \text{ pc}$ )

VHE



VHE Flare

HST-1

Core

No Core

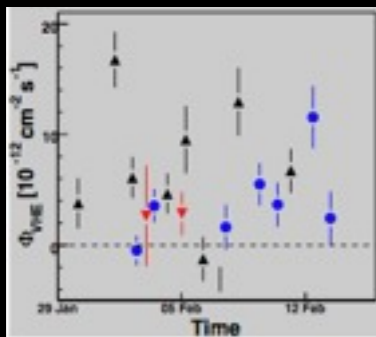
X-ray

Radio



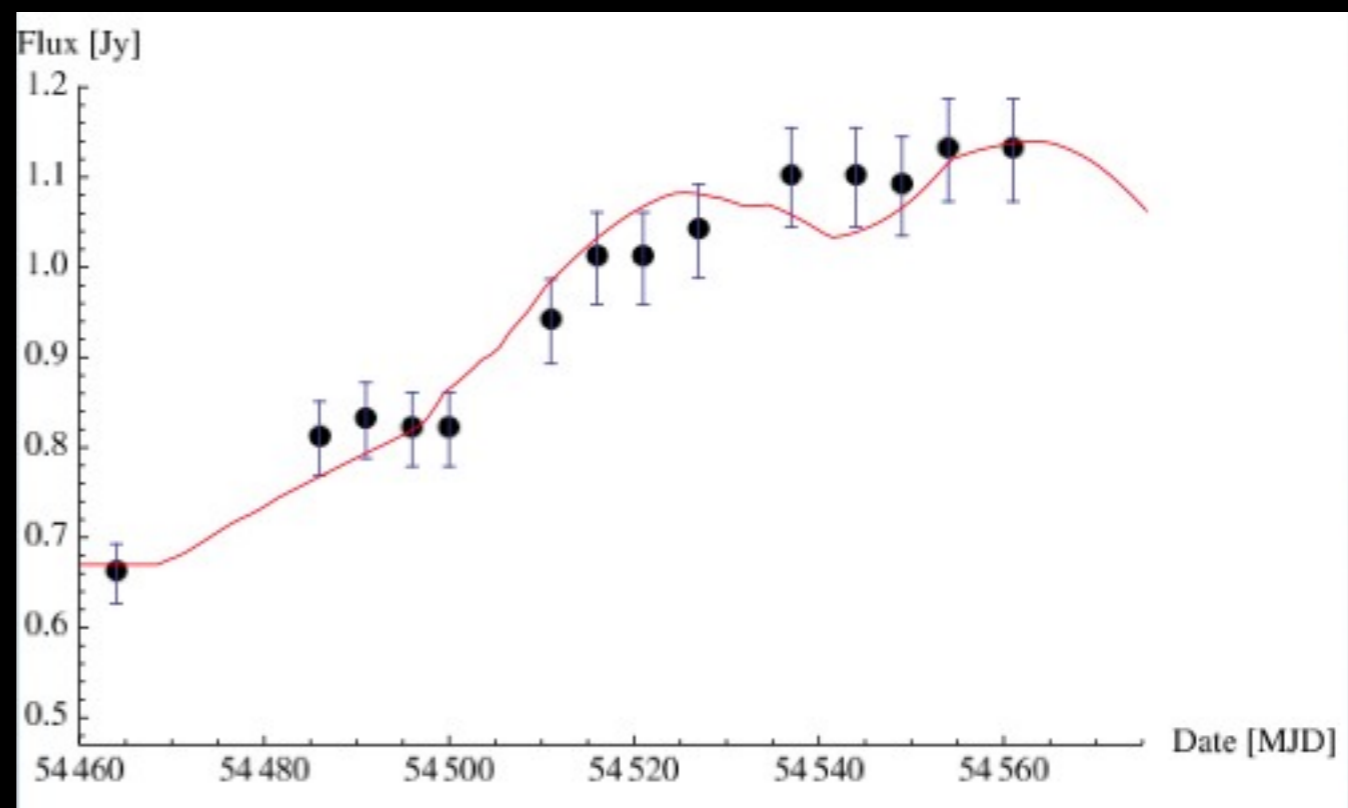
# Why does the Radio Flux slowly Rise?

Using VHE lightcurve  
as a source function

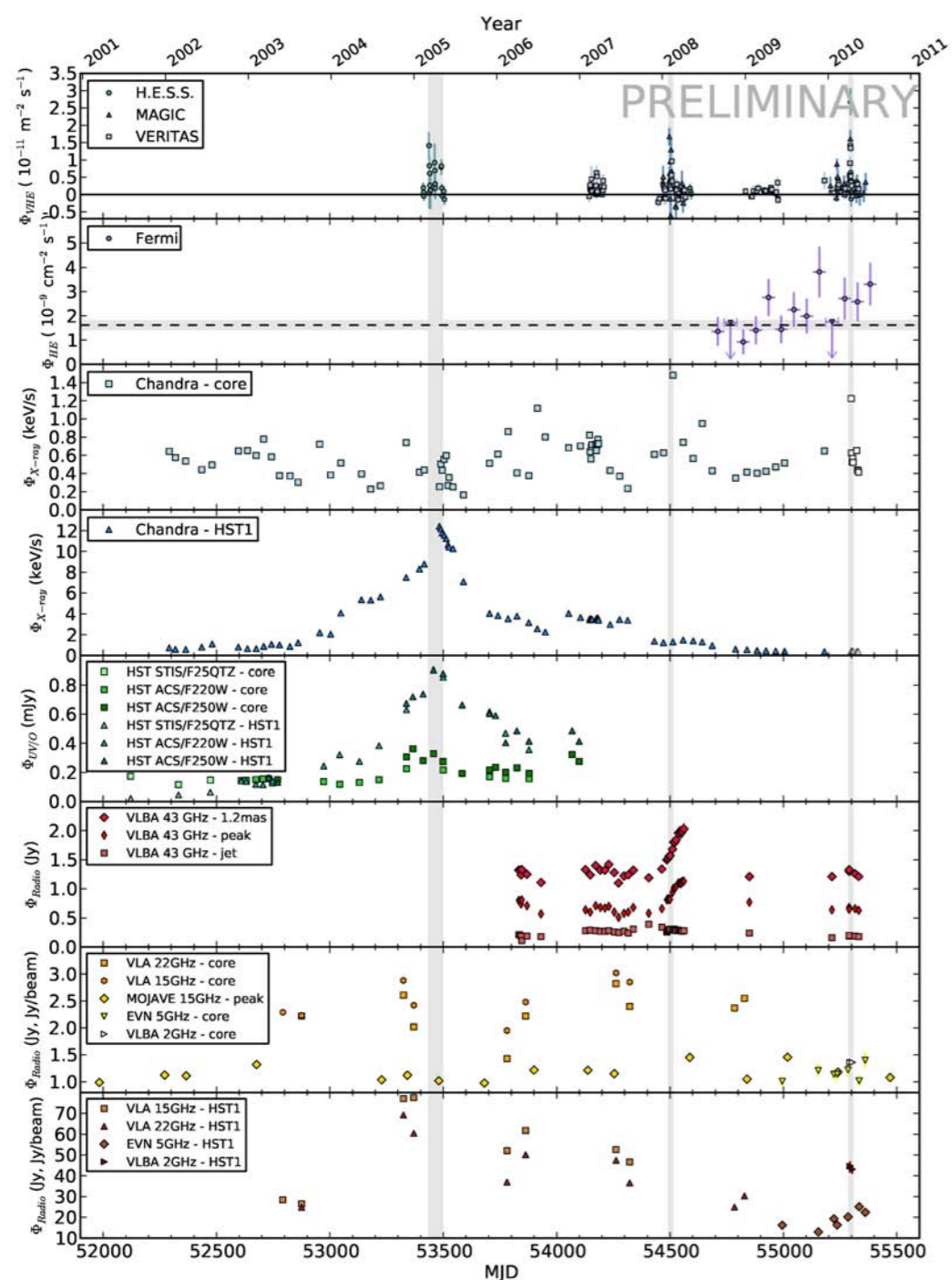


Inject Electrons into a 'slow  
outer sheath' of jet plasma

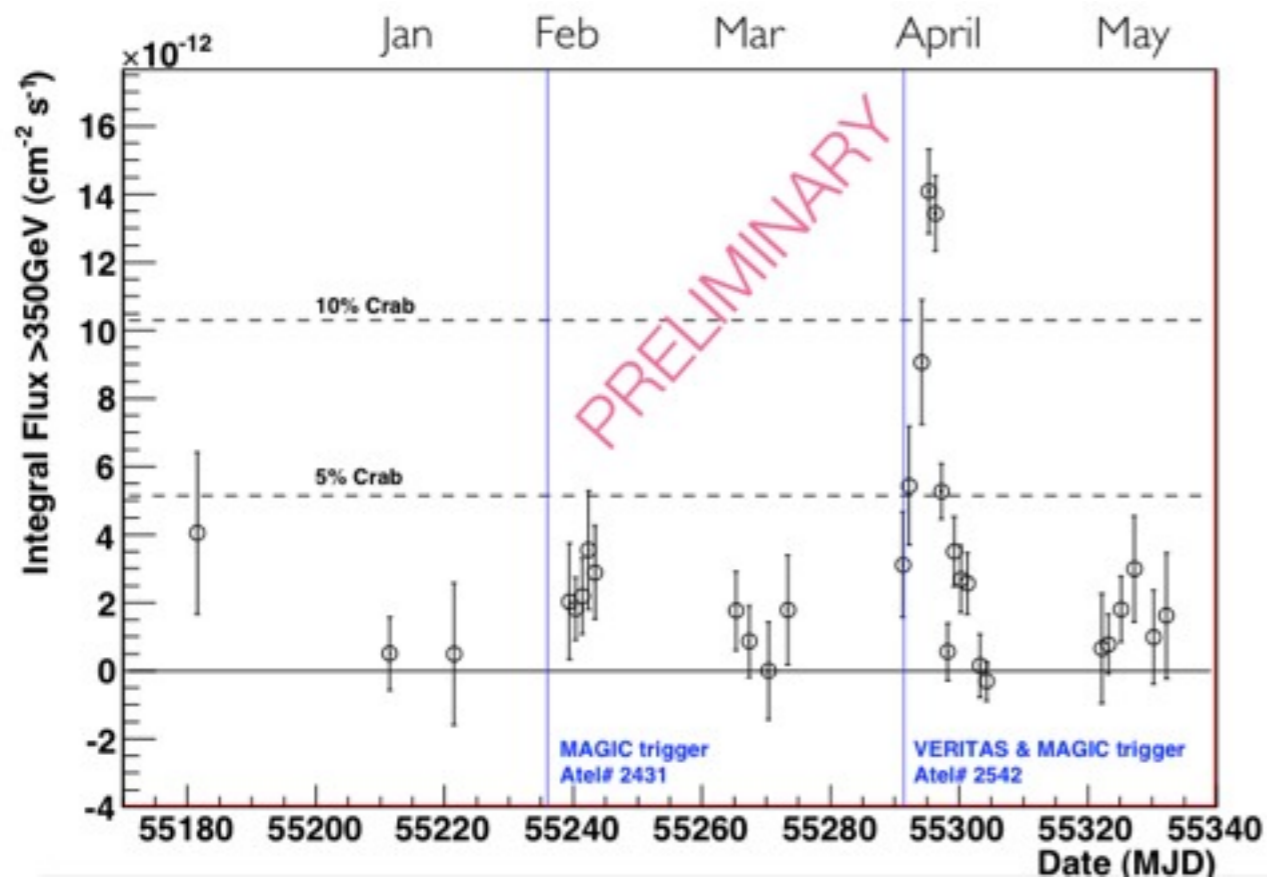
Radio-emitting  
plasma is optically  
thick at the  
beginning but then  
expands and thins  
out optically



Accurately model the 43 GHz radio light  
curve as synchrotron self absorbed flux



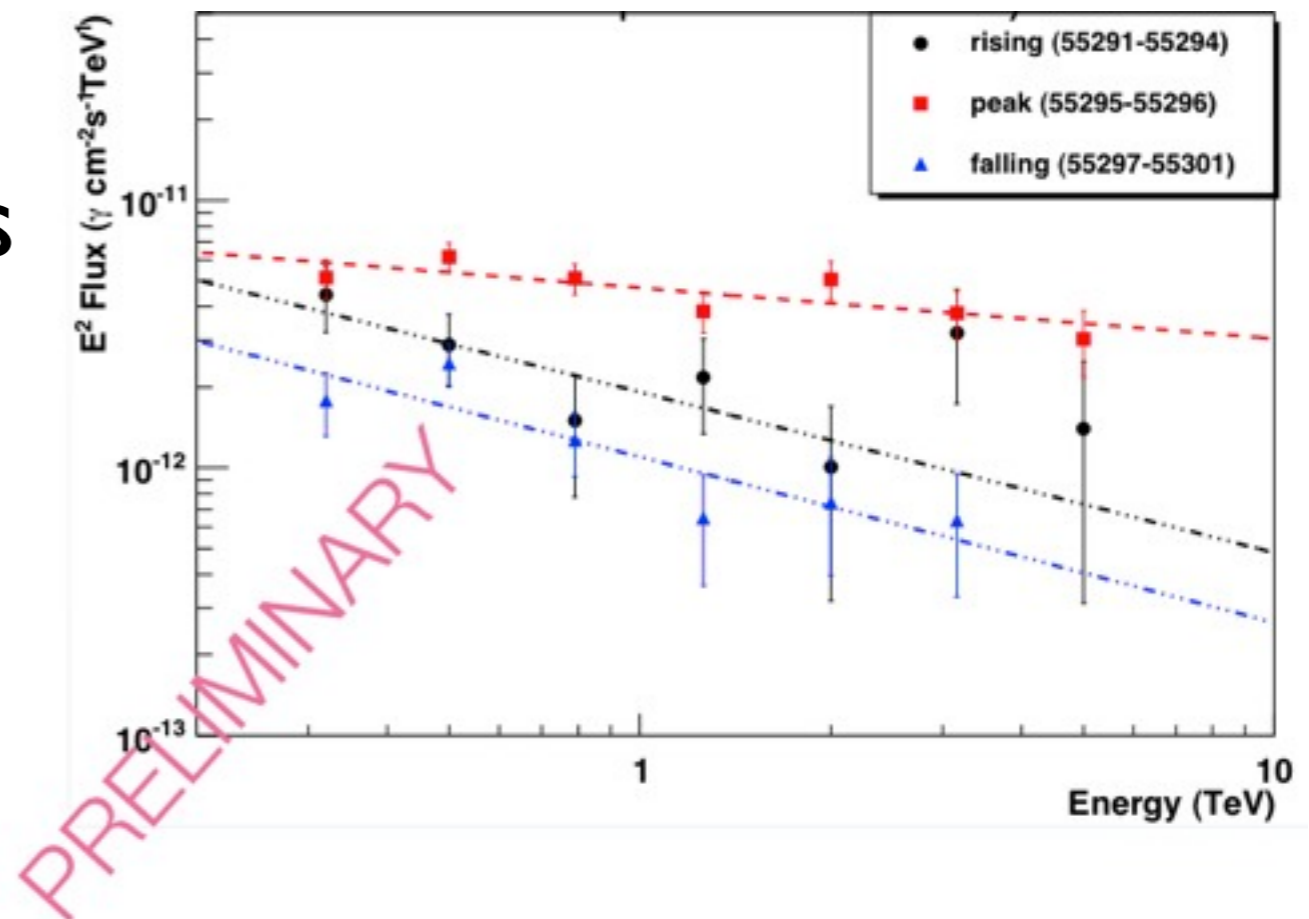
- 2005 TeV flare (HESS) coincided with X-ray/UV/radio flaring in knot HST-1 ( $> 120 \text{ pc}$ )
- 2008 TeV flare (VERITAS, MAGIC, HESS) coincided with radio flaring in core (sub-pc)
- 2010 TeV  $\sim 20\%$  Crab (highest ever) with LAT, VLBA and Chandra Coverage

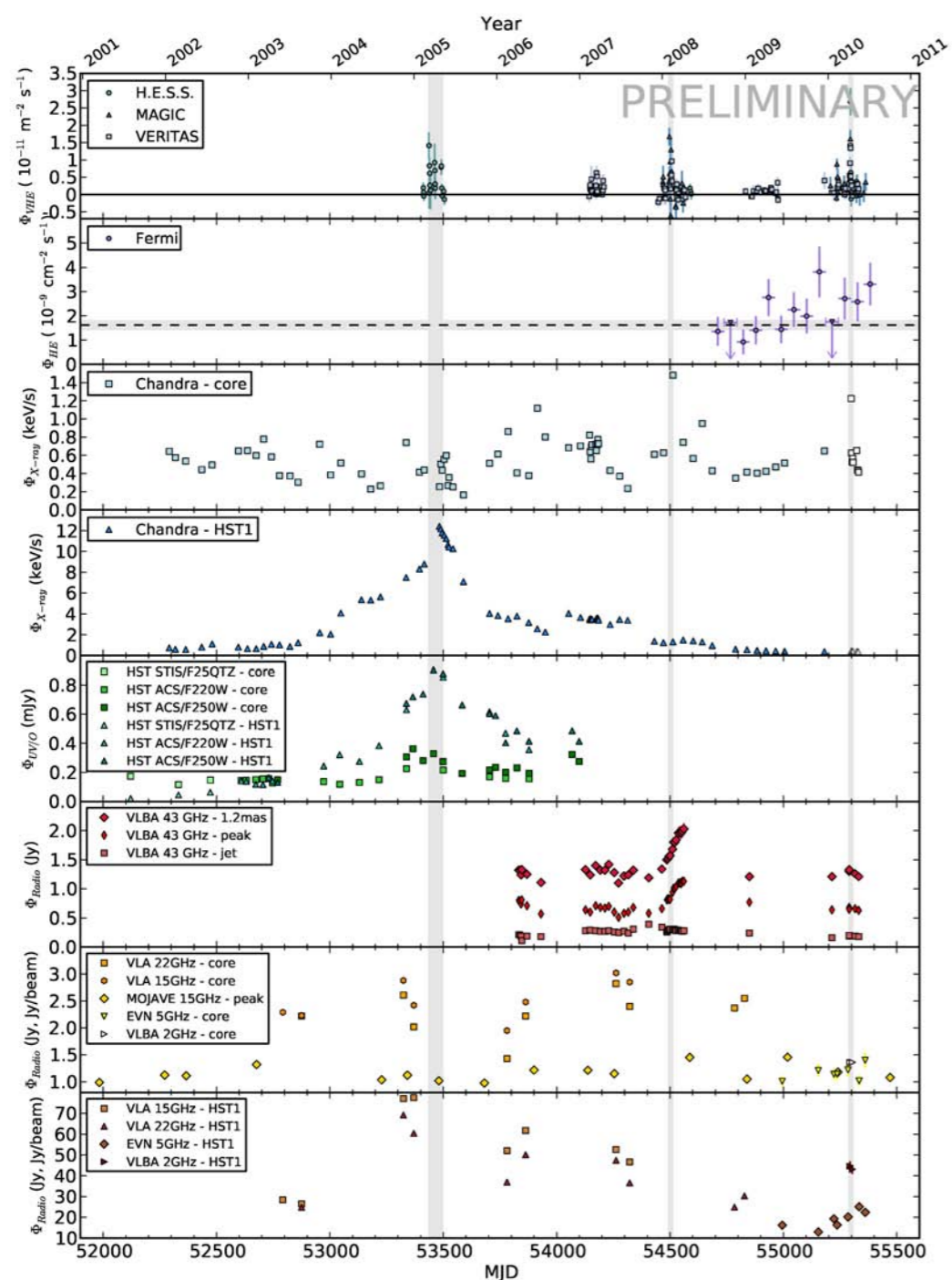


Brightest VHE flare  
ever seen (~20%  
Crab)

Enough photons to divide  
spectra into different states

1. *Rising*  $\gamma = 2.60 \pm 0.31$
2. *Peak*  $\gamma = 2.19 \pm 0.07$
3. *Fading*  $\gamma = 2.62 \pm 0.18$





- 2005 TeV flare (HESS) coincided with X-ray/UV/radio flaring in knot HST-1 ( $> 120 \text{ pc}$ )
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- 2010 TeV  $\sim 20\%$  Crab (highest ever) with LAT, VLBA and Chandra Coverage

# Conclusions

- Highly variable objects need highly coordinated multiwavelength campaigns.
- Next generation will see many more of these - but monitoring + campaigning will still be the key. Use radio and HE to detect high states (keep *Fermi* going...)